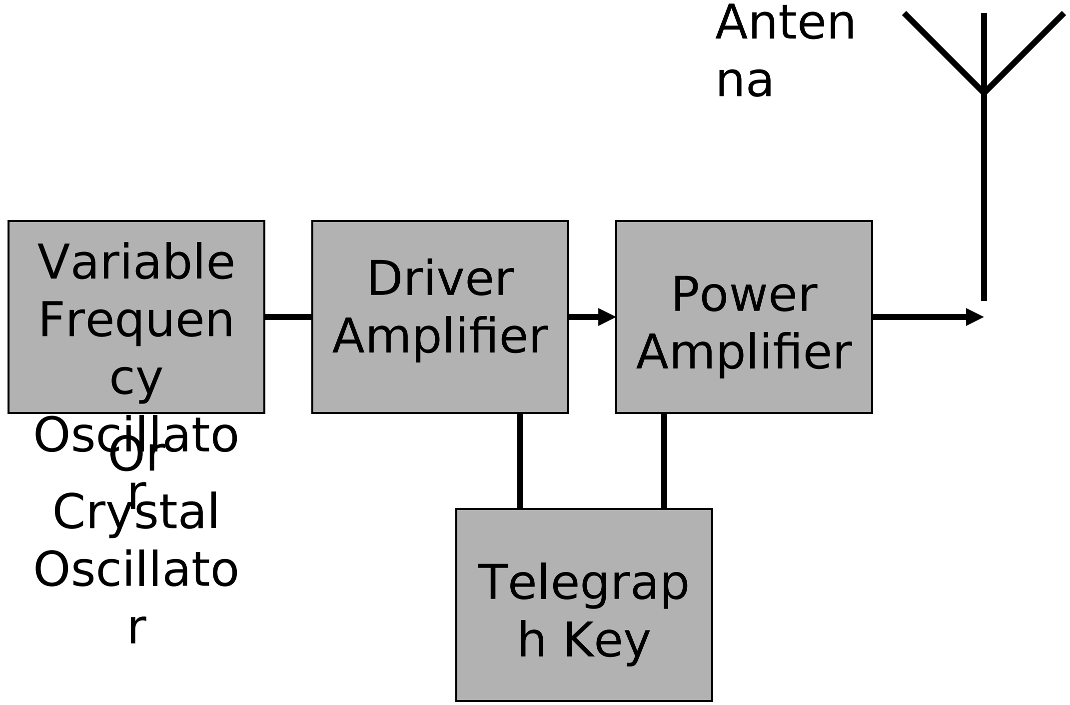
RF Emissions & Antenna Fundamentals

The Basic Transmitter



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Station Setup:

$$SWR = \frac{1 + \sqrt{\frac{\text{Reflected Power}}{\text{Forward Power}}}}{1 - \sqrt{\frac{\text{Reflected Power}}{\text{Forward Power}}}}$$

Transceiver — SWR Bridge — Antenna Tuner — Antenna Switch — Dipole Antenna / Beam Antenna / Dummy Load

An SWR Bridge measures Standing Wave Ratios. In a perfectly matched antenna system (1:1), theoretically, all power sent "Forward" to the antenna would be transmitted. However, this is not ever the case. A portion of the power sent to the antenna actually passes back down the feed line. If this "Reverse Power" is of high wattage, it could damage the transmitter or even the operator! Modern

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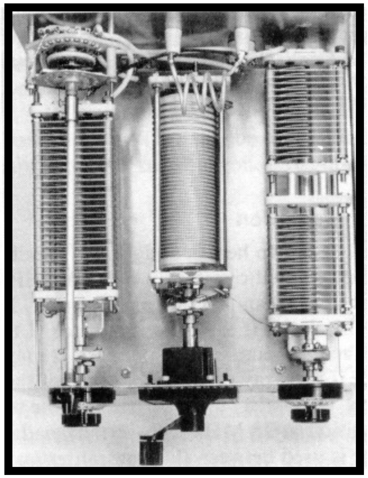
Station Setup:

- One Variable Inductor Coil.
- Two Variable Capacitors.
- Used also on random-wire antennas.



Pi-Network also called a Transmatch or antenna tuner.

Transceiver — SWR Bridge — Antenna Tuner — Antenna Switch

Antenna Switch — Dipole Antenna

Antenna Switch — Beam Antenna

Antenna Switch — Dummy Load

An Antenna Tuner functions as an "Impedance Matching" device. Today's transceivers require a 50 ohm impedance. A mismatched antenna or line represents a high or low impedance resulting in a high SWR. A simple Pi-Network is used to match the transmitter's requirement of 50 ohms to whatever impedance is presented at the feed-line. Antenna tuners do present a loss of signal, and should be

An Antenna Switch is nothing more than a switch...let's proceed to Antenna

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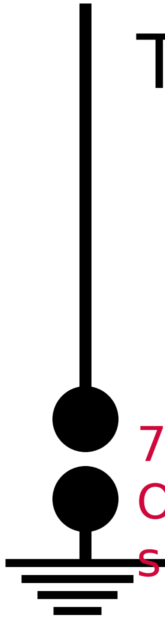


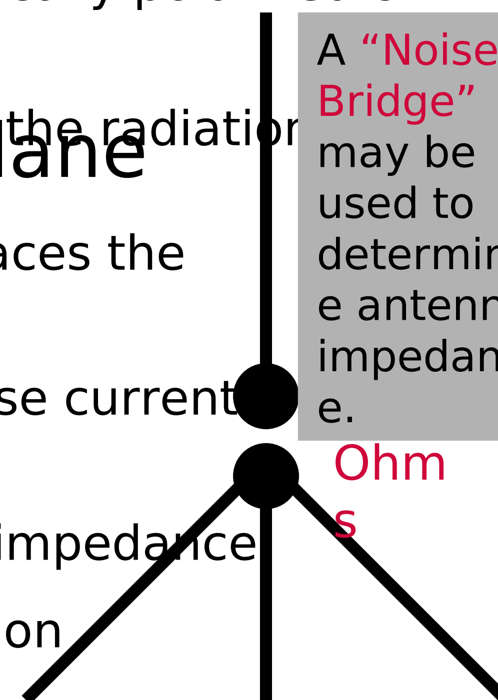
The ¼ Wave Vertical

- Is the simplest of all antennas.
- Formula for construction is 234/frequency in MHz.
- Is vertically polarized with a low angle of radiation.
- Man made noise is vertically polarized & signal ground loss.
- High current points are the radiation at ground level!

The ¼ Wave Ground-Plane

- Adding multiple ¼ wave legs replaces the ground.
- Antenna is elevated to raise to raise current point.
- Lowering the ground-plane drops impedance.
- Raised antennas reduce RF radiation exposure.

A "Noise Bridge" may be used to determine antenna impedance.



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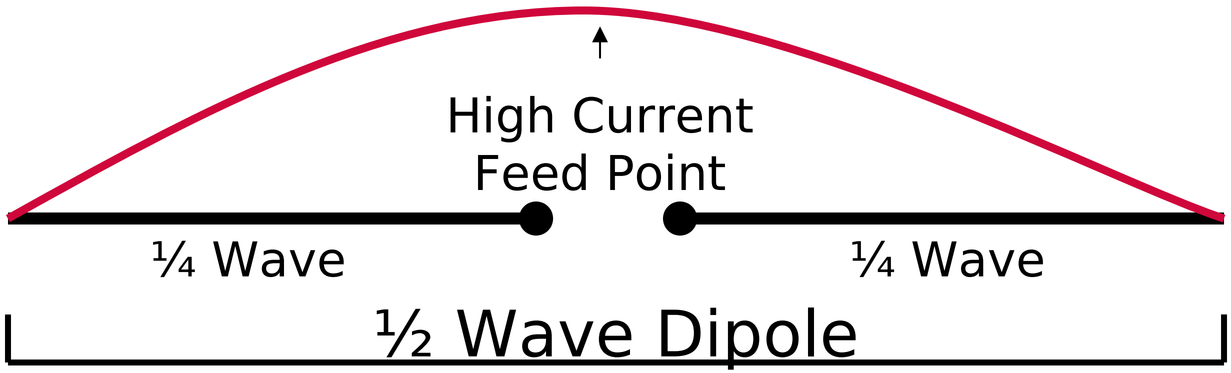
The Dipole Antenna



- Construction determined from 468/frequency in MHz.
- Has a feed-point impedance of approximately 72 Ohms.
- Has a horizontal polarization.
- Can be easily constructed in minutes.
- Can be rotated for directional properties (Radiation: 90 degrees to face).
- Can function for odd harmonics of the primary frequency.
- Usually feed with 72 ohm coax, or twin-lead.
- If 50 ohm coax is used, a 1-to-1 balun should also be

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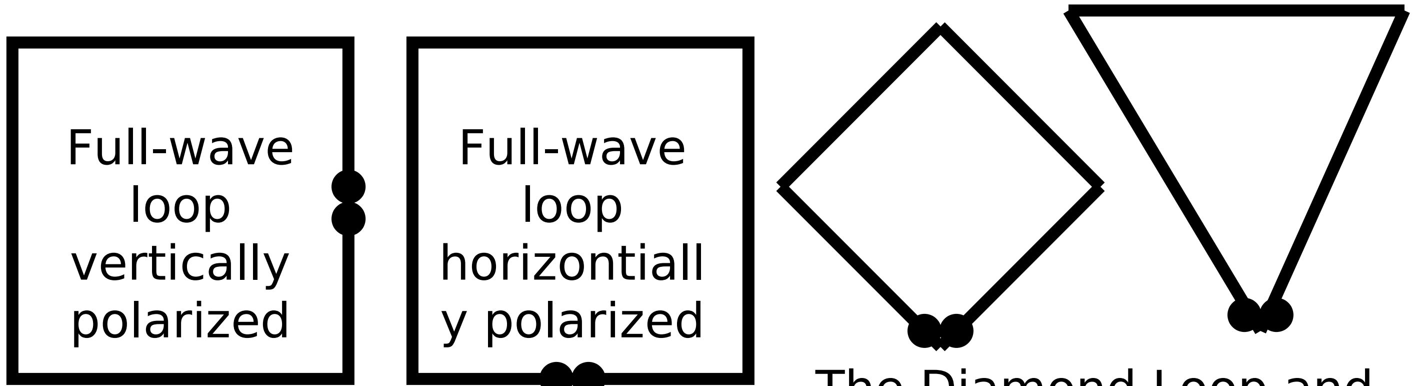
Full-Wave Loops



*Each side is ¼ wavelength!

The Diamond Loop and the Delta Loop have diagonal polarization, with properties of both vertical and horizontal antennas.

- Construction: 1005/frequency in MHz.
- Is quiet because it’s a closed-circuit.
- Has multiple polarization options.
- Has an impedance of about 96 ohms.
- Requires ¼ wave of 72 ohm coax as matching transformer.
- Has 2.5 db gain over a dipole, over 3 db gain compared to a vertical.
- Every 3 db is the same as doubling your power

Antenna Theory: *Yagi Theory*

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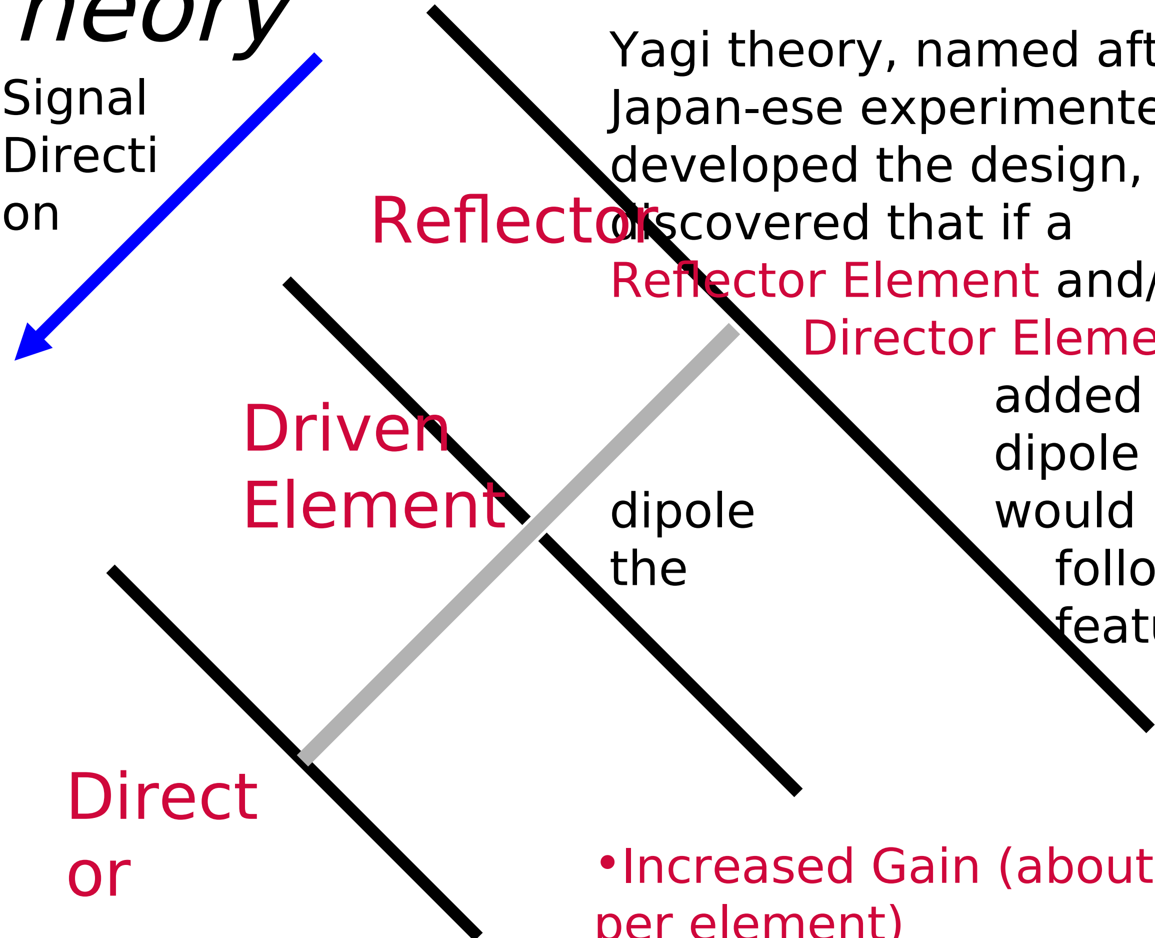

Yagi theory, named after a Japan-ese experimenter who developed the design, discovered that if a Reflector Element and/or Director Element was added to a dipole the dipole would have the following features…

- Increased Gain (about 2db per element)
- Front-to-back signal rejection ratio.
- Sharper directivity & side rejection.

Parasitic Element Formulas:

Director – 458/freq. in MHz.

Driven – 472/freq. in MHz.

Antenna Theory: *Yagi Theory*

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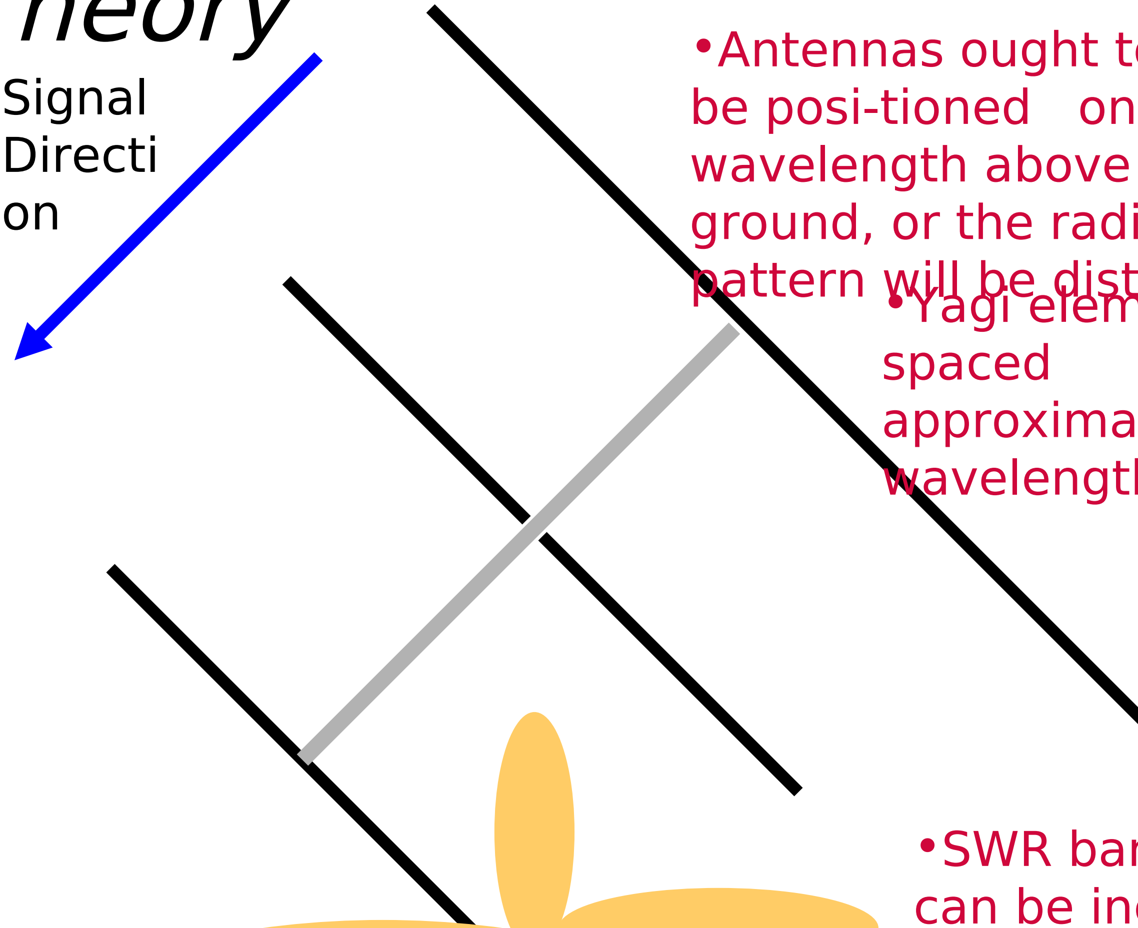

- Antennas ought to ideally be posi-tioned one wavelength above the ground, or the radiation pattern will be distorted.
- Yagi elements are spaced approximately .1 wavelength apart.
- Yagis may be mono-band… or multiband when using traps.
- SWR bandwidth can be increased on Yagi's by using larger diameter elements.

Yagi's produce a main radiation lobe of the front of the antenna with minor lobes off the sides and back.

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- The strength of a signal radiating from an antenna, as well as the radiation pattern emanating from an antenna, can be determined using a “Field-Strength-Meter”.
- If a signal reads 1 millivolt in strength at a distance of 5 wavelengths, it would read .50 millivolts at 10 wavelengths. (1 x [5/10 = 50%] = .50)
- “Per-Square-Meter” measurements…remember to devise the square-root of the per-square-meter measurement, then figure as above.

Example: If the free-space far-field power density of an antenna measures 9 milliwatts per square meter at a distance of 5 wavelengths, what will the field strength measure at a distance of 15 wavelengths?

Answer: The square of 9 = 3

divided by [15/5 =33.3%]

= 1

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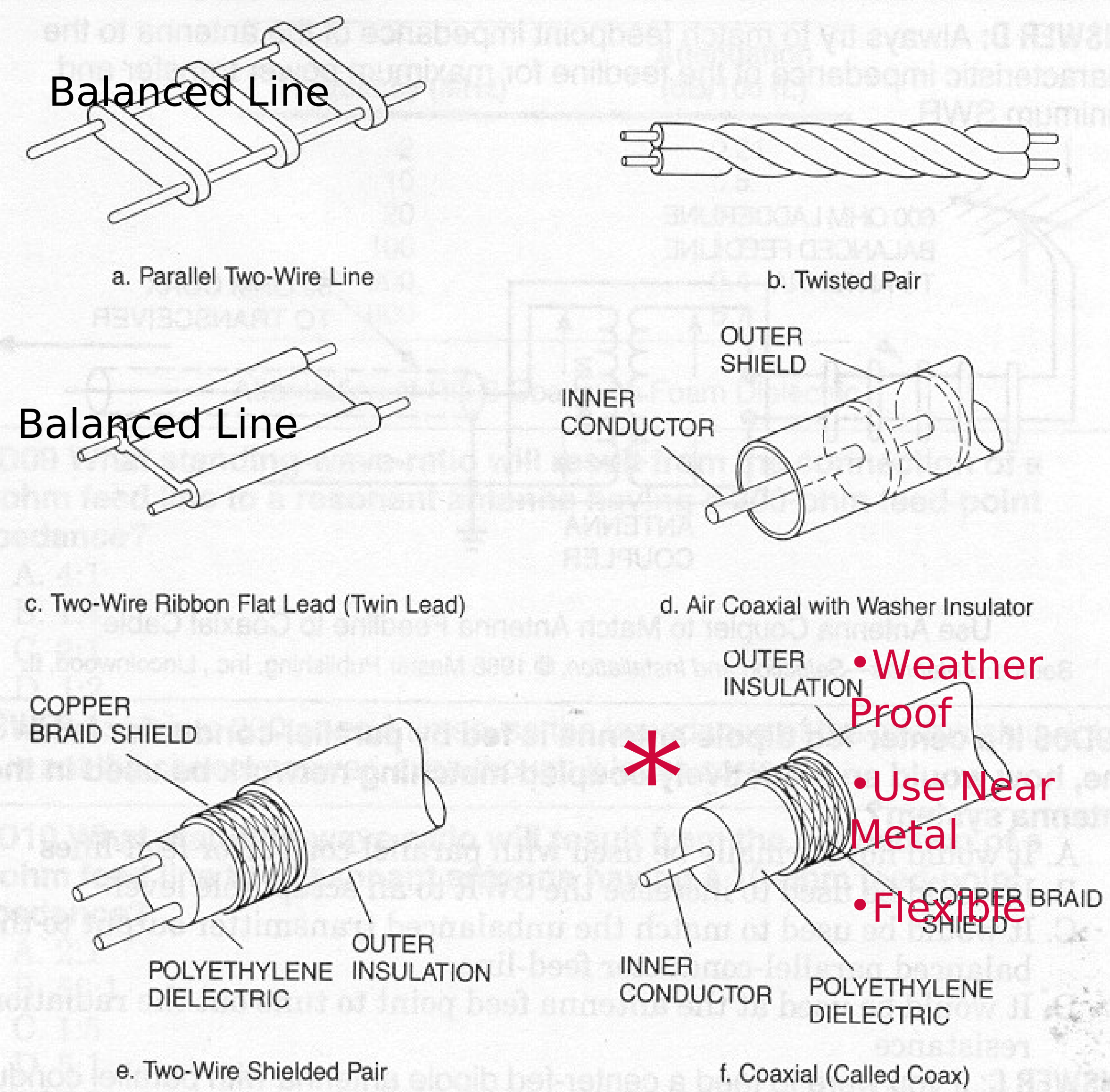

Different Transmission Lines

Source: *Antennas—Selection and Installation*, © 1986 Master Publishing, Inc., Lincolnwood, IL

Ladder-Line…

300-600 Ohm

Twisted Pair…

? Ohm

Ribbon…

300 or 72 ohm

Air Coax…

Variable ohms

Shielded Pair…

Variable ohms

Coax…

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- Impedance of a parallel-line (Ladder-line) changes with spacing of the two wires, and the size of the two wires.
- Coax has losses. The longer the coax, the greater the signal loss. The efficiency of a coax cable is expressed in terms of “db loss per 100 feet”. The higher the frequency, the greater the db loss per 100 feet.
- SWR, Standing Wave Ratios, are usually caused by an impedanc mis-match between the antenna and the feed line. A 50 ohm feed line connected to a 200 ohm antenna results in a 4:1 SWR, or a 50 ohm coax connected to a 10 ohm antenna results in a 5:1 SWR (Say good bye to your radio!).
- Baluns are matching transformers used at the antenna feed point. An antenna with a 200 ohm impedance can be fed by a 50 ohm coax if a 4:1 balun is used.
- An inductively coupled matching network (A balun or a transmatch) is used at the connection between the unbalanced transmitter output and the balanced parallel-line connection.

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- It is a good idea to use the minimum amount of power necessary when transmitting with a hand-held in order to reduce the level of RF radiation exposure to the operator’s head.
- The FCC RF regulations are most stringent for frequencies between 30 MHz and 300 MHz, <u>your body absorbs this RF most easily</u>.
- RF exposure can cause heating of the eye which may result in the formation of cataracts. RF Absorption heats the body.
- The density of radiated power from its source is proportional to the inverse square of the distance. The distance from the antenna is most important.
- “Field Strength”, the strength of the RF field radiating from your antenna varies with the type of antenna used.
- Looking into the open end of a microwave horn antenna will expose your eyes to RF radiation.
- Amateur Radio Operators are required to meet FCC RF radiation exposure limits to ensure a safe operating environment for amateurs, their families, and neighbors.
- The *Maximum Permissible Exposure* (MPE) levels are not uniform throughout the radio spectrum because the human body absorbs energy differently at various frequencies.

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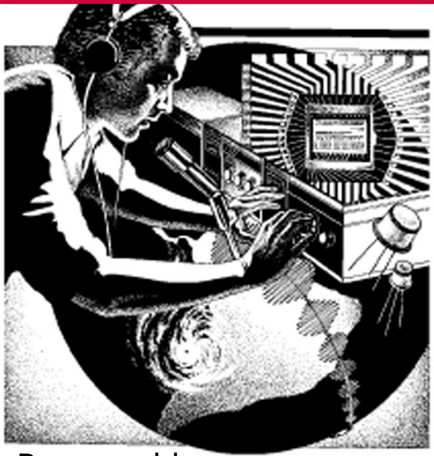

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- A station is assumed to be in compliance with the FCC radiation regulations if:

  Part 97.13(c)(1): The station's Peak-Envelope-Power to the antenna (ERP) is less than...

160m	500 watts
80m	500 watts
40m	500 watts
30m	425 watts
20m	225 watts
17m	125 watts
15m	100 watts
12m	75 watts
10m	50 watts
VHF Bands	50 watts

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•The term "Specific Absorption Rate" (SAR) refers to the rate at which RF energy is absorbed into the human body.

•The *Maximum Permissible Exposure* (MPE) is based upon the whole-body specific absorption rate (SAR).

•The FCC RF radiation maximum Permissible Exposure (MPE) limits are defined in the FCC Part 1 and Office of Engineering and Technology (OET) Bulletin 65.

•A site with multiple transmitters must multiply all their RF radiation according to the number of transmitters. All operators are equally responsible.

•<u>Duty Cycle</u>, <u>Power Density</u> and <u>Frequency</u> are all important in estimating RF energy's effect on body tissue.

•<u>Specific Absorption Rate (SAR)</u> is calculated as W/kg, and is the unit of measurement that best describes the biological affects of RF fields.

•"<u>Thermal Affect</u>" refers to bodily damage from RF heating the body, "<u>Athermal Affects</u>" are non-heating bodily damages.

•Time Averaging refers to the total amount of exposure averaged over a certain time…6 minutes for controlled environments, or 30 minutes for uncontrolled environments.

MPE Calculator program…http://www.qsl.net/w0jec/

•Electric Fields (E) divided by Magnetic Fields (H) will

RF Radiation – *Free Space Far Field St*

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$$\text{Power Density}_2 = \text{Power Density}_1 \times \frac{(\text{Distance}_1)^2}{(\text{Distance}_2)^2} = 9\,\frac{\text{mW}}{\text{m}^2} \times \frac{(5\,\lambda)^2}{(15\,\lambda)^2}$$

$$= 9\,\frac{\text{mW}}{\text{m}^2} \times \frac{25\,\lambda^2}{225\,\lambda^2} = 9\,\frac{\text{mW}}{\text{m}^2} \times \frac{1}{9} = 1\,\frac{\text{mW}}{\text{m}^2}$$

You might also reach this answer by recognizing that the ratio of the distances squared is 9. Then you can divide by that value to get the new power density.

Power density is related to the square of the electric and magnetic field strengths. This means that the electric and magnetic field strengths will decrease linearly with distance. We can write another equation for field strength, then:

$$\text{Field Strength}_1 \times \text{Distance}_1 = \text{Field Strength}_2 \times \text{Distance}_2 \qquad \text{(Equation 10-5)}$$

We can also solve this equation for Field Strength$_2$ and write a new equation.

$$\text{Field Strength}_2 = \text{Field Strength}_1 \times \frac{\text{Distance}_1}{\text{Distance}_2} \qquad \text{(Equation 10-6)}$$

In this case you can simply multiply by the ratio of the distances.

For example, suppose you measure the electric field strength 5 wavelengths from a 10-MHz dipole antenna, and you get a reading of 1.0 millivolts per meter. What will the field strength be at a distance of 10 wavelengths?

$$\text{Field Strength}_2 = 1.0\,\frac{\text{mV}}{\text{m}} \times \frac{5\,\lambda}{10\,\lambda} = 1.0\,\frac{\text{mV}}{\text{m}} \times \frac{1}{2} = 0.50\,\frac{\text{mV}}{\text{m}}$$

As another example, suppose you measure the free-space far-field strength of a 28-MHz Yagi antenna to be 4.0 mV / m at a distance of 5 wavelengths from the antenna. What will the field strength be 20 wavelengths from the antenna?

$$\text{Field Strength}_2 = 4.0\,\frac{\text{mV}}{\text{m}} \times \frac{5\,\lambda}{20\,\lambda} = 4.0\,\frac{\text{mV}}{\text{m}} \times \frac{1}{4} = 1.0\,\frac{\text{mV}}{\text{m}}$$

As a final example of this type of calculation, let's suppose you calculate the free-space far-field electric field strength of a 1.8-MHz dipole antenna at a distance of 4 wavelengths from the antenna. If the field strength is 9 microvolts per meter, what will it be at a distance of 12 wavelengths from the antenna?

$$\text{Field Strength}_2 = 9.0\,\frac{\mu\text{V}}{\text{m}} \times \frac{4\,\lambda}{12\,\lambda} = 9.0\,\frac{\mu\text{V}}{\text{m}} \times \frac{1}{3} = 3.0\,\frac{\mu\text{V}}{\text{m}}$$

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- If your repeater station antenna will be located at a site that is occupied by antennas for transmitters in other services, you must consider your radiatied signal, along with all other radiated signals, when determining RF exposure levels.
- To determine compliance with the maximum permitted exposure (MPE) levels, safe exposure levels for RF energy are averaged over an "Uncontrolled" period of 30 minutes.
- To determine compliance with the maximum permitted exposure (MPE) levels, safe exposure levels for FR energy are averaged for a "Controlled" period of 6 Minutes.
- You will be required to indicate your understanding of the FCC rules regarding FR exposure on your FCC license application.
- All Amateur stations are required to submit to the FCC RF exposure rules. It is the licensee's responsibility to ensure compliance.
- The "Duty Cycle", the period of time a transmitter is operating a full power, determines the amount of RF exposure.
  1. The lower the duty cycle, the shorter the compliance distance from the antenna to the neighboring environment
- See the FCC OET Bulletin 65 (Link below) for ways to measure power density

www.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet65

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•Never touch an antenna when transmitting, it will result in RF burns!

•Keep all antennas as high and away from people as possible. VHF mobile antennas on the center of the vehicle roof.

•For the lowest RF exposure to passengers, mobile antennas ought to be placed on the roof of the vehicle.

•When working on transmitters and amplifiers, make sure they cannot be accidentally turned on before removing their RF shielding, this is a protection against accidental shock and RF exposure.

•A good way to avoid stray RF energy in the radio shack is to keep all ground connections as short as possible. Long ground wires may act more like an antenna causing RF burns if touched.

•The greatest RF exposure factor, out of all factors, is the frequency of the signal.

•The unit of measurement that best describe the biological effects of RF fields is “The Specific Absorption Rate” (W/kg).

•“Athermal Effects” refer to RF exposure effects other than body tissue heating.

Ham Radio

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- If measurements indicate that your station is exposing you to more than the maximum permissible level of radiation, you should…

1) Ensure proper grounding of the equipment.
2) Ensure all equipment covers are tightly fastened.
3) Use the minimum amount of transmitting power necessary.

- When installing an antenna…

1) Install the antenna as high and away from populated areas as possible.
2) If the antenna is a gain antenna, point it away from populated areas.
3) Minimize feed-line radiation into populated areas.

- A dummy load provides a safe RF environment because the dummy load is a poor radiator that converts RF into heat.
- The advantage of a high-gain antenna is that the radiation can more effectively be directed away from populated areas.
- The disadvantage of high-gain antennas is that

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End of Lesson 4